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Developing a framework for knowledge creation, dissemination and utilisation for smes : a case study of biotechnology

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Introduction

The realisation that fast growing SMEs are major contributors to economic prosperity has seen these firms being increasingly attributed with a more central role in the development of wealth, innovation, employment and national competitiveness. Spatial proximity often positively affects knowledge spillovers from firms and research organisations, reinforcing the asymmetric economic geography of prosperity and accomplishment (Cooke et al, 2005). Moreover, the multi-faceted nature of innovation processes highlighted by Leyesdorff (2000) suggests this should involve the examination of wide-ranging relationships (e.g. with other firms, government agencies, universities). Relating this to geographical aspects in particular, has been the identification of regional systems of innovation as extensions of national systems (Cooke and Morgan, 1994, Morgan, 1997, Howells, 2002, Baptista and Swann, 1998). Whilst national systems of innovation focus on the central role that knowledge and innovation play in determining productivity and growth (Lundvall, 1992, Nelson, 1992), regional factors help

determine the extent of individual and organisational learning, technology transfer, innovation and business performance that subsequently occurs within individual regions (Oughton et al, 2002, Howells, 2002, Asheim and Gertler, 2005).

Additionally, whilst network arrangements are often seen on a broad scale as a foundation for economic growth, this can also be evaluated at the level of the regional economy (see Brusco 1982; Brusco and Righi 1989) where promotion of geographically-based entrepreneurial networks and clusters often occurs (Kinsella 1989), suggesting a particular importance for proximity in these processes. In terms of innovation, for example, there is evidence that learning and therefore innovation occurs through interactive, iterative and networked approaches (Weick, 1990; Cooke, 1998).

Evaluation of the supply of knowledge and its characteristics, however, also needs to be accompanied by that of the capabilities of knowledge users and effectiveness of knowledge transfer/translation (Cooke et al., 1997; Braczyk and Heidenreich1998). There is a clear need, therefore, to link the knowledge and innovation created and disseminated, with commercialised outcomes in terms of product and process innovation and improved firm capacity and growth. The arguments surrounding this can be encapsulated within the knowledge spillover theory of entrepreneurship. This argues, essentially, that knowledge developed in some institutions might be commercialized by other institutions, and that entrepreneurship is one way that the 'economic agent with a given endowment of new knowledge' can best appropriate the returns from that knowledge (Acs et al. 2004). Audretsch and Lehmann (2005) demonstrated, for example, that the number of new firms located close to a university is positively influenced by knowledge capacity. In this sense, knowledge capacity was measured by spending on R&D and technological innovations of the region and the knowledge output of universities.

The complexity of knowledge intensive entrepreneurship often creates further barriers for firm behaviours. This may be result from (1) failure of private firms and public institutions to generate new knowledge; (2) failure of that knowledge to be disseminated efficiently; (3) failure of individuals to exploit new knowledge; (4) a range of other factors that make entrepreneurship difficult. Thus, the absence of a domestic industry base and/or the absence of domestic knowledge-creating institutions, such as public research institutes, might mitigate against the emergence of knowledge-based entrepreneurship (Audretsch and Lehmann 2005).

Those individuals or organizations with market knowledge or other resources may not be aware of the new knowledge, and therefore fail to invest, or under-invest, in the knowledge or in new firms (Audretsch, 2004). In addition, individuals may also fail to commercialise new knowledge via entrepreneurship, if they underinvest in commercialization activities or fail in their attempts to commercialize due to a lack of market knowledge.

There is also evidence, however, that knowledge-creating collaborations as well as disseminating mechanism can be non-local in nature. A recent study into the effects of social capital on SME performance, for example, found that both higher growing and more innovative firms tend to make greater use of non-local networks (Cooke et al. 2005). In addition, Acs et al (2007) highlight that new knowledge can be imported into a region through the activities of foreign multinationals. This highlights a need to evaluate the importance of both local and non-local linkages in knowledge-based SME innovation and growth processes.

This issue requires an evaluation of the supply of knowledge and its characteristics, the capabilities of knowledge users and the effectiveness of knowledge transfer/translation (e.g. Cooke et al). This paper develops a framework to examine these issues at both local and non-local levels, using the knowledge-intensive biotechnology sector as a case study, specifically that in Australia, due to its nature as a knowledge-intensive industry, with clear knowledge-spillovers via public institutions, a plethora of SMEs, potential international linkages and strong government policies at both national and regional levels. The paper is thus structured as follows. Following examination of the literature, a broad conceptual framework established. In the methodology section, the biotechnology industry generally is then examined using this framework, and the methods for analysing the Australian biotechnology industry outlined. The results from the Australian biotechnology industry are then analysed, with conclusions concerning the analytical framework, this industry, and the potential focus for future research, discussed.

Literature: Growth, Innovation, Knowledge, Entrepreneurship and Networks

Knowledge creation and utilisation has become a cornerstone of modern economic activity and policymakers have increasingly sought ways to encourage this value adding activity. Researchers also increasingly acknowledge that, due to rapidly changing and highly competitive markets, growth oriented small firms are starting to exert a significant influence on national economies (Yeh-Yun-Lin 1998) and are responsible for making a disproportionate

contribution to wealth and employment creation (Delmar and Davidsson 1998; O'Gorman 2000). These high growth firms are also more often found in more dynamic industries and regions (Carroll and Hannan, 2000; Davidsson and Delmar, 2001), often related to both innovation and external linkages (Wynarczyk and Watson, 2005; Havnes and Senneseth, 2001. Whilst the literature suggests that the use of external linkages (both in terms of market consumption and product development) can impact positively upon growth through innovation and knowledge creation, the strength of relationship between innovation and growth may not always be strong (e.g. see Cooke et al, 2005). In the knowledge-spillover theory of entrepreneurship (Acs et al. 2004), for example, it is argued, that levels of knowledge-based entrepreneurship might be affected by (1) the ability of private firms and public institutions to generate new knowledge; (2) the degree to which this new knowledge is disseminated to the wider economy and (3) the degree to which individuals and firms are able to exploit this new knowledge.

Investment in the creation of new knowledge generates opportunities for entrepreneurs (Audretsch and Lehmann, 2005). The absence of a domestic industry base and/or the absence of domestic knowledge-creating institutions, such as public research institutes, might thus mitigate against the emergence of knowledge-based entrepreneurship (Audretsch and Lehmann 2005), as might the absence of foreign multinationals in a region, able to import such knowledge from outside. Additionally, however, individuals or organizations with market knowledge or other resources may not be aware of the new knowledge because of a lack of dissemination, and therefore fail to invest, or under-invest, in the knowledge or in new firms (Audretsch, 2004). Finally, individuals may also fail to commercialise new knowledge via entrepreneurship, if they underinvest in commercialization activities or fail in their attempts to commercialize due to a lack of market knowledge, ability to manage the new knowledge effectively or insufficient entrepreneurial ability. As regional knowledge and innovation systems are dynamic and evolving, therefore, these issues can also be affected by the nature of the region itself. This thus generates a 3 stage process of knowledge creation, dissemination and utilisation, in which entrepreneurship (and entrepreneurs) sits at the centre of a regional innovation system. This process, however, requires further "unpacking" before a full framework for analysis can be developed.

Beginning with knowledge creation, conventional processes for fostering organisational learning and innovation, based primarily on individual behaviour and linear models are now

viewed increasingly as the exception rather than the norm, it being increasingly acknowledged that learning, knowledge creation and innovation occur through highly interactive, iterative, networked approaches (Lundvall 1992; Weick, 1990; Cooke, 1998). Current paradigms therefore emphasize the need for multi-disciplinary and interactive knowledge production between governments, universities, research institutions, and firms in relevant industries. Indeed, Etzkowitz and Leydesdorff (1997) developed the 'Triple Helix' framework arguing that innovation occurs at the intersections between government, university and industry.

Frenz et al (2005) discovered, however, that the level of UK firm-UK university cooperation is very low, concluding more generally, that firms must have a certain level of absorptive capacity (defined by the proportion of science and engineering graduates in the workforce, level of firm R&D expenditure, and organizational capability) before entering into cooperation with a university. Once established, however, this cooperation was found to have a positive and significant effect on innovation. They also argued that the most consistent finding to come out of regional total factor productivity growth studies was that the stock of human capital enhances the absorptive capacity of firms, facilitating local technology transfer, local and regional knowledge spillovers and growth. If knowledge generation encompasses the "triple-helix" elements of Leyesdorff's (2000) model there also appears to be a need, therefore, to also consider the factors which help stimulate, manage and diffuse created knowledge and innovation, as part of an overall knowledge and innovation management framework. Links between SME growth, innovation, and networking, for example, has led to an increasing focus on entrepreneurial firms networked together in various ways (Asheim and Coenen, 2006), Gordon and McCann (2000) identifying three sets of advantages in geographically based clusters and networks, derived from agglomeration (i.e. from external economies of scale, scope and complexity).

Crucial here, are issues surrounding the management of networks, the structures and fora in which the actors operate and the role of education and training and processes of learning, to enable networked knowledge processes. There are a range of fora and structures, for example, in which and through which knowledge creation and dissemination can occur, including direct spinouts of companies, and collaborations with various stakeholder groupings from industry supply chains, government institutions and universities. Cluster and network theory also suggests a range of other formal and informal mechanisms in which knowledge creation and

dissemination can also be encouraged. The suitability of the structures and for a used, however, will be factors of crucial importance in determining the success or otherwise of the knowledge creation and dissemination process.

Encouraging the take-up of new innovations through dissemination via education and training also allows individuals to be provided with knowledge about the innovation itself, as well as being inspired and convinced of the possibilities for success and mutual gain (Goffin, and Mitchell 2005). Such explicit, codified knowledge can, however, be encapsulated in formats and transferred to users who are able to interpret and utilise it independently from the context in which it was created, (Howells, 2002). The transfer of codified knowledge is not seen as strongly dependent on geography as codified knowledge can be transferred across geographic regions fairly readily, and reductions in costs and improved communications increase access to codified knowledge, rendering it less important as a source of competitive advantage. Tacit knowledge, it has been argued, however, does not always travel well, making it a key source of 'the *geography* of innovation' (Asheim and Gertler, 2005). This includes knowledge flows between firms, research organisations, institutions and public agencies that are embedded in a regional context. Frenz and Ougthon (2006), therefore, argue that, since proximity facilitates the transfer of tacit knowledge transfer and learning - both of which are important determinants of innovation - innovation activity takes on a strong regional dimension that may be reinforced by agglomeration economies in production and pools of skilled labour/human capital.

Effective and appropriate management of innovation creation and diffusion structures and fora are also vital to this process. In this respect, the three basic modes or mechanisms that can be applied are hierarchial state or corporation based, or the market, or social networks (Lowndes and Skelcker, 1998). Markets are sometimes, however, perceived as unable to adequately bundle the relevant resources and capacities between science and industry, and the complete vertical integration inherent in hierarchy restricts flexibility and incentives (Menard, 2002). Conversely pure networks of relationships based on trust and reciprocity are often insufficient forces to secure necessary directed outcomes (Rhodes 1997; Keast, and Brown 2002). Hybrid approaches therefore have the ability to limit or balance out the negative effects of an over-reliance on one governance mode (Menard 2002), through exhibiting a number of possible combinations and recombinations of contract and trust to form effective strategic partnerships (Schaeffer and Loveridge 2002). Again, the suitability of the management

mechanism used in the situation at hand will be important in determining the success or failure of the creation and dissemination process, particularly given that there are a range of processes and motivations of importance when examining these issues, depending on the nature of the network being utilised.

The relationship between learning, structures and governance modes provide the mechanisms to bring participants (and the various stakeholders) together to share resources and knowledge that are present in individuals or organisations. One scenario, for example, might see a myriad of key stakeholders from industry, government, and institutions (including universities and government research departments), utilising these interconnected mechanisms to generate and disseminate knowledge, innovation, skills, and training, and to operate management and governance structures appropriate to their own particular circumstances.

Evaluation of the supply of knowledge and its characteristics also, however, needs to be evaluated through the lens of the capabilities of knowledge users and effectiveness of knowledge transfer/translation (Cooke et al., 1997; Braczyk and Heidenreich, 1998). In order to exploit knowledge created and disseminated through networks, however, there is also the crucial role that entrepreneurship itself plays in the process. In particular, entrepreneurs require appropriate personal 'knowledge', resources and management abilities, encapsulated in the factors of entrepreneurial orientation, appropriate strategic evaluations seen in asymmetric knowledge provision between existing activities and the innovation, and appropriate knowledge management (Senyard, 2007). The issue of knowledge asymmetry, however, is a complex one as new knowledge by its very nature creates knowledge asymmetry (or lack of proximity between old and new knowledge – Boschma, 2005). This asymmetry cannot be too large for firms receiving knowledge, however, as they will be unable to use the knowledge received, and some symmetry of information is thus critical for relationships development and success as it develops trust (Fukuyama, 1995, Baranson, 1990), which positively affects decisions to maintain the relationship and creates stability through shared understandings and norms. Knowledge asymmetries exist because of differences in knowledge, business processes and resources (Brooksbank et al. 2007). Cimon (2004) further evaluated and categorised asymmetries as (1) information asymmetries; (2) knowledge asymmetries; and (3) learning asymmetries, with all three recognised as having a role to play in the process of organizational knowledge creation (Nonaka and Takeuchi, 1995;

Ancori *et al.*, 2000), and arising from differing resource endowments (e.g. Barney, 1991) and absorptive capacity (Cohen and Levinthal, 1990).

The way in which this new knowledge is then managed will also be crucial for the strategic direction of the firm in many industries (Dyer et al., 2001). It is argued that firms should be able to increase their competitive performance through effective knowledge management, strategic learning and knowledge orientation, and that these are positively related to long term survival and growth (Salojarvi et al 2005; Matlay 2000). Salojarvi et al (2005) also state that firm success often depends upon an organisation's ability to create, utilise and develop knowledge-based assets. Despite this it is somewhat surprising that relatively few studies have examined the links between knowledge management and firm growth,. Instead, studies have concentrated upon knowledge management alone in SMEs (e.g. Kautz and Thaysen, 2001; Wickert and Herschel, 2001). Successful innovation requires managers to match 'technical' expertise, in areas such as technology and project management, with 'soft' skills in people management, to promote creativity. Few managers are either educated or experienced in both of these areas (Goffin, and Mitchell 2005, p. 27). Kirby (2004) thus advocates the use of Higher Education Institutions (HEIs) in promoting and reinforcing the development of such entrepreneurial skills in communication, creativity, critical thinking and assessment, leadership, negotiation, problem-solving, social networking skills, and time-management. These are all equally applicable to the creation and utilization of knowledge, the links with HEI also highlighting ways in which links can be made between external network and internal-firm-based processes.

Effective entrepreneurial behaviour is also necessary to prosper in competitive environments (Covin and Slevin, 1988, Lumpkin and Dess, 1996, Miller, 1983 and Zahra, 1993a). within this context entrepreneurship plays a pivotal role in facilitating links between research and industry (Abramson et al., 1997). Utilising Covin and Slevin's (1989) "basic unidimensional strategic orientation" concept a firm's behaviour can be catergorised along a continuum that ranges from highly conservative to highly entrepreneurial behaviour in which a firm's position is referred to as its entrepreneurial orientation (EO) (see Barringer and Bluedorn, 1999; Lumpkin and Dess, 1996). The three main dimensions of EO are innovation, proactiveness and risk. Previous studies (see Table 1) have consistently highlighted a positive relationship between EO and performance.

Table 1: Dimensions of Entrepreneurial Orientation

Author	Dimension	Sample	Statistical Analysis	Study Conclusion
Lee, et al (2001)	Innovation, Risk Taking Proactiveness	137 Korean Tech Start Ups	Regression, Correlation	EO has positive, marginally statistically significant effect on performance.
Voss et al (2005)	Innovation, Risk Taking, Proactiveness, Competition Scanning, Autonomy	324 US Theatre Groups	Regression, Correlation	Relationship between stakeholder influence and EO behaviors is transparent, managers develop reciprocal, strategic relationships that reinforce valued behaviors. When the interaction between stakeholder influence and EO behaviors is less transparent, managers must perform a balancing act to contend with complex, pluralistic and conflicting stakeholder demands and responses.
Zhou et al (2005)	Opportunity Recognition, Environmental Sensitivity, Environmental change and challenges	China 350 respondents to brand	Structural Equation Modeling Factor Analysis	EO has a more positive impact on tech based and market-based innovation when competition is intense
Wiklund and Shepard (2005)	Proactiveness, Innovativeness, and Risk taking	465 Swedish Manufacturing and services firm	regression analysis and correlation	EO positively influences small business performance. High EO, high access to capital, and environmental dynamism did not increase performance.
Poon et al (2006)	Innovation, Risk Taking, Proactiveness	96 small firms	Regression, Correlation	EO did not mediate the relationship between internal locus of control and firm performance. EO is a necessary mediator of the link between generalized self-efficacy and firm performance.

Synthesising these multi-faceted relationships between knowledge, how it is disseminated through the network, innovation processes and growth, creates a comprehensive evaluation framework as follows:

- *Knowledge-creation* relationships (i.e. between firms, government and its agencies, and institutions, such as universities) .

- How *knowledge-dissemination* occurs though the fora or structures for disseminating knowledge (e.g. via spinouts, alliances, collaborative networks etc.), management and governance of the relationships between the sets of actors, and the education, training and learning required for effective dissemination.
- *knowledge-utilisation by the companies themselves for innovation-specific and more general growth-related outcomes*, by examining knowledge asymmetry (degree to which the knowledge is new / overlapping with existing knowledge), its management and synergy with strategic behaviours and plans that relates to entrepreneurial orientation in maximising the benefits of the knowledge.

Despite the importance placed on geographical proximity in the literature highlighted however, there is also evidence, that these processes can also have a wider geographical element. Acs et al (2007) point out, for example, that foreign multinationals can be used to import new knowledge into a region (in their examples Ireland and Hungary). Freel's (2003) study of West Midlands manufacturing firms, found evidence of innovators making use of external links (particularly supply chain links), where proximity not seen as significant, and indeed innovators were more likely to have cross-locality links of a more geographically dispersed nature. Both Boschma (2005) and Frenz and Oughton's (2006) reviews of the theoretical research also suggest that the borders of innovation systems can be blurred (also see Narula, 2003) as the growing importance of trade and multinational enterprises (Simmie *et al* 2002) create sectoral and technological processes that cross national and regional borders (Malerba, 2002). Moreover, Lambert's UK study (2003) submits that for business-university collaborations, the importance of physical proximity is inversely related to the physical proximity of the firm's largest market, with firms who focus primarily on local market predominately cooperating with their local university (88 per cent), and firms with a significant international market orientation cooperate more widely with national (48 per cent) and international universities (26 per cent). Frenz and Ougthon (2006) summarise these potentially overlapping geographical relationships in terms of the following:

- Elements of the global system of innovation include multinational enterprise and trading (importing, exporting and flows of knowledge) activities;
- National innovation systems that include infrastructure, institutions, education and training, governances system, and the inter-linkages and networks between them;

- Regional systems of innovation boundaries which are determined by the geographic spread of clusters, public administration, physical infrastructure, pools of skilled labour, training structures, institutions, the degree of networking and linkages, and industry and firm specificities;
- Industry sector systems may also then cross regional and country boundaries;
- Technological systems based on generic platforms (such as ICT) may also be applied across sectors, regions and countries.

These overlaps indicate that, whilst local and regional systems may provide external economies of scale, the degree of openness to national and global systems is also important (Simmie, *et al* 2002). A recent study of the effects of social capital on the performance of small and medium sized enterprises (SMEs) in twelve UK regions also found that innovative firms make greater use of cross-locality networks (CLNs) (Cooke et al. 2005), which supplement other spillover-based means of obtaining new knowledge and innovations. Putnam (2000) makes the key distinction between two forms of social capital- 'bonding' and 'bridging', such that low levels of autonomy are consistent with the dominance of the former over the latter. Bonding social capital represents an 'exclusive' set of relationships, characterised for example by special interest groups, families, or based along ethnic lines, and so on. Conversely bridging social capital is more 'inclusive', and could exist for example within civil rights groups, and other cross-cultural organizations. With respect to economic development, Putnam suggests that the primary use of bonding social capital is to 'get by', while that of bridging social capital is to 'get ahead'. As such, the former is typically employed in situations of group solidarity, for example community finance and start-up, ethnic business, etc. The latter however can provide access to resources such as new political contacts and new job opportunities. It is important to note here that the over-reliance on bonding social capital carries with it the potential for negative consequences for the user. For example, once a business has reached a certain size, it may find itself obligated to inefficient suppliers within its' 'home' network, or unable to access new markets and sources of large-scale finance.

Boschma's (2005) paper also identifies five dimensions of proximity that can have an impact on learning and knowledge, and which, crucially, do not necessarily require geographical proximity. He argues that the need for geographical proximity for learning to occur is weak when there is a clear division of precise tasks that are coordinated by a strong central

authority—organizational proximity—and the partners share the same cognitive experience—cognitive proximity (Boschma 2005: 69). He further suggests that spatial lock-in may be solved or even avoided by establishing non-local linkages. Findings from several empirical studies also suggest that non-local as well as local relationships are important sources for interactive learning (see Asheim and Coenen 2006, Jaffe et al. 1993, Feldman 1994). Boschma (2005) suggests that shared formal institution structures [such as laws, rules and regulations that are the subject of governance] are not necessarily bound by geographic proximity. Instead, institutional structures can reflect a kind of balance between institutional stability (reducing uncertainty and opportunism) openness (providing opportunities for newcomers) and flexibility (experimenting with new institutions). To satisfy the need for co-presence to exchange tacit knowledge, CLNs could bring people together through, for example, occasional travel (Boschma 2005). Asheim and Coenen (2006) argue, therefore, that there is a need for both local and distant networks for effective process and product innovation. This highlights the need, for factors related to knowledge (and its influence upon innovation and growth) to be examined within the SME and at both local and cross-local levels.

Methodology

In order to begin to test this framework, there is a need for in-depth study of these processes within knowledge-based industries. Available literature suggests that the biotechnology industry may be suitable for this task. Biotechnology is viewed as an enabling technology and, as such, has been embraced by governments to drive economic growth and improve the quality of human life. The development of a biotechnology industry has also been seen to benefit from a governmental policy framework aiming to compensate for market failures (Orsenigo, 1989). Access to resources and incentives, in particular financial resources from government, is of great importance in any theory explaining biotechnology (Harman & Harman, 2004). Without this, the level of R & D spending would be less than the optimum for the economy (Erskinomics Consulting, 2003). To this end, global growth of the biotechnology industry is occurring. The number of publicly listed biotechnology firms on NASDAQ, for example, increased from 265 firms in 1994 to 314 firms in 2004. In addition, the increase in the market capitalization of these firms changed from $45 billion in 1994 to $311 billion in 2003 (Ernst & Young, 2004). Small biotechnology companies often hold the key to most of the next generation of blockbuster drugs, without which the large US

pharmaceutical companies would see a huge downturn in profits as the patents expire on their existing successfuly products. Knowledge in the biotechnology firm also, often evolves as a result of synthesis of scientific, technological and business knowledge, and managerial skills, these knowledge systems are coevolving as the firm develops (Liyanage & Barnard, 2003). Therefore a firm's capability is a continuous synthesis of scientific, technological and managerial skills and knowledge requiring input from organisational learning and management strategies (Lane & Lubatkin, 1998; Zahra & George, 2002; Zollo & Winter, 2002) The advancement of the biotechnology industry is thus critically bound by knowledge and information asymmetries associated with scientific, technological and business related knowledge (Murray, 2002).

Cooke and Laurentis (2006) also found, that UK universities and firms in the UK biotech sector, commonly enter into collaboration with overseas partners in addition to partners within the UK, for product innovation, distribution, licensing deals and supply contracts; and as such the UK biotechnology sector operates in a global marketplace. Many foreign multinational biotech firms also have manufacturing or research operations in the UK, located as a result of acquisitions of mergers, as well as Greenfield investment. There is also clustering activity associated with biopharmaceuticals firm interaction patterns, strongly demonstrative of substantial clustering, looser collaboration and more focused co-operation activities. Moreover co-operation is especially pronounced with regard to *innovation* activities and interactions. This, however, is by no means limited to interactions within the home region cluster. UK biopharmaceuticals firms interact most with global partners, next with UK partners and only then cluster and EU partners. With specific regard to *innovation*, as distinct from other interactions such as research, joint patenting, purchasing or supplying, and other more informal collaboration, the act of *commercialising* new knowledge in the form of a product or service new to the firm or new to the market, Cooke and Laurentis (2006) found that UK biotechnology firms also innovate collaboratively. These firms innovate in partnership with other actors in their region, mainly their cluster, to an equivalent amount that they innovate in partnership with actors in the EU. However, they innovate more than either of those categories with partners in the UK more generally, and finally their *innovation* partner is most likely to be outside Europe, actually the USA or to a lesser extent Asia in most cases. Specifically, biotechnology genomics firms often have no desire to conduct R&D with local competitors because they already know its likely content due to the open availability of

much of this knowledge and localised knowledge spillovers among firms competing in highly specific local niches. In the absence of distant spillovers from other sources, therefore, firms form collaborator relations with 'distant networks' to augment R&D knowledge for themselves. These occur broadly equally in the EU and North America, as well as more extensively in the home country itself.

This suggests that the biotechnology industry generally exhibits the knowledge generation, dissemination, utilisation mechanisms highlighted within the broad framework synthesised from the literature. In order to examine these processes in more depth, however, the case study nation of Australia was chosen. This research and analysis occurred within the 2005-2006 period , when Australia's biotechnology industry was experiencing growth. Market capital as at December 2005 for biotechnology, medical devices and other healthcare companies whose stocks are listed on the Australian Stock Exchange (ASX) is A$42.4 billion (157 companies) up from A$27.1 billion in 2004 (Australia Government Initiative, 2006). Partly as a result, Australia now has more biotechnology companies relative to GDP than any country except Canada **(**IMB 2005). In 2006, there were 427 core biotechnology firms with 625 firms in medical devices (Ausbiotech 2007). The majority of these being small to medium enterprises, recorded in the Australian biotechnology industry (Hopper & Thorburn 2005). There is, however, a relative paucity of research of this important industry in the Australian context (Senyard, 2007), and in particular, an evaluation of the factors of importance to government policy when seeking to encourage the industry's successful development and growth.

The method chosen to examine the issues in the Australian context was a combination of analysis of secondary literature sources, combined with in-depth interviews with a range of key stakeholders, purposively selected e.g. see Patton, 1990 based on their role in the industry. These stakeholders in the 'triple helix' included industry professionals (including industry association Ausbiotech members, commercialisation managers, venture capitalists, biotechnology employment specialists, entrepreneurial managers of established start ups) Government (both Federal and State Government), and academia (scientists, commercialisation managers). Owing to confidentiality arrangements, the individuals are not explicitly identified. The research protocol included open-ended questions to allow a natural conversation flow around the common set of issues (Patton, 1987). In addition, 3 case study

companies were also, chosen, in order to examine the role and importance of the internal firm-level activities in the knowledge utilization (commercialisation) process.

Results

The results of the interviews conducted are now briefly outlined in terms of examining the context and role of the 3 main sets of stakeholders (the industry and its firms, government and university). These results indicate the heavily government-influenced nature of industry-policy highlights the crucial need to examine how government policies affect behaviour in this industry, in terms of outcomes, funding allocation, and knowledge management, the evidence suggesting a very hierarchy-based approach from government. This contrasts with the more market-based approach towards which university management of spinout processes seemed to be moving, and the seemingly more network governance based approach that commercialisation managers are employing in their dealings with the academic scientists, highlighting hybrid governance currently at work, with respondents questioning the effectiveness of such behaviour. The three case studies of firms show varying stages of firm development. The first case study, is still conducting clinical trials and is publicly listed on the Australian Stock Exchange. It retains close links with its affiliated university (who retains share ownership) and is, at present, looking for large global pharmaceutical partners to continue product development. The second firm, the most established of the three, has been very successful in the global markets and continues to develop new products. The third case study evaluates a business which no longer operates. The cases were purposively selected to highlight different outcomes, product definition, age, and thus provide a snapshot of strategic behaviours (entrepreneurial orientation), knowledge asymmetry, and knowledge management characteristics of the companies.

In terms of the Australian biotechnology industry and knowledge creation policies, there has been a particularly strong Australian federal government policy in place, in conjunction with university institutions and the government, as highlighted in table 2 below.

Table 2: Summary of Australian Government Policies: "Backing Australia's Ability" and "National Biotechnology" Strategies

Package	Overview	Total Funding and	Key Human Resources Strategies

		Duration	
Backing Australia's Ability (BAA I and II)	General science and Innovation package, focused on three key elements in the innovation process: • strengthening Australia's ability to generate ideas and undertake research; • accelerating the commercial application of ideas; and • developing and retaining Australian skills.	Total duration: 2001-11. Total Funding: $8.3billion.	**Developing and Retaining Skills** The package supports the long-term sustainability of Australia's skill base in the enabling sciences and the encouragement of positive attitudes toward science and innovation in the community. It promotes this by: • Funding an extra 5740 higher education places in ICT, mathematics and science at Australian universities ($350.5m) • Improve teaching in Innovation, Science, Technology and Mathematics ($38.8m) • Enhance capabilities of government schools to build stronger scientific, mathematical and technological skills of Australian students and to encourage school-based innovation ($373m). • Questacon Smart Moves: an initiative to raise awareness of science and innovation among young Australians and encourage participation in science and innovation industries ($15.1m) • Science Connections Programme: initiative to raise awareness of the contributions of science and innovation in the broader Australian community ($25.8)

National Biotechnology Strategy (NBS)	Provides a framework for the development of biotechnology in Australia. The strategy addresses six key themes: • Biotechnology in the community; • Ensuring effective regulation; • Biotechnology in the Economy; • Australian biotechnology in the global market; • Resources for biotechnology; and • Maintaining momentum and coordination	Total duration: 2000-08. Received initial funding of $30.5m in 2000, followed by additional contributions of $66.5m and $20m through BAA I and II.	**HR for Biotechnology Development** The key objectives are: • enhance management skills in the biotechnology sector; • attract high quality researchers and experienced leaders; • encourage entrepreneurship; and • monitor demand and supply for specialist skills. The key strategies are: • Improve management of research, intellectual property and technology within established firms and new enterprises; • Develop, attract, motivate and retain high quality researchers, particularly in those fields where Australia has strong capacities to commercialize research outcomes; • Maximize technological awareness and capabilities throughout industries that will be developing and applying biotechnology • Develop programs and systems to foster entrepreneurship • Monitor emerging skills needs in the biotechnology sector and develop appropriate responses.

Source: Stephens et al (2006)

According to Stephens et al (2006), Australian biotechnology, also has a research strength underpinned by its universities, its federal research body (Commonwealth Scientific and Industrial Research Organisation (CSIRO), and other leading institutions. The majority of Australian biotechnology firms in 2004 (60 per cent) are less than six years old (Department of Industry Tourism and Resources, 2004) and the industry is developing through small, dedicated entrepreneurial firms staffed mostly by scientists (Curtis et al, 2006). Australian State Government initiatives have also shown an increased focus on biotechnology research creation, dissemination and utilisation agendas. Specifically, current programs developed by the Smart State Strategy (Queensland Biotechnology Strategic Plan 2005) include:

- Smart State Innovation Projects Fund: Consists of $60 million over the next four years to support national and international alliances and collaborations between research organisations and industry.
- Biotechnology Commercialisation Pipeline: Assists new biotechnology firms to access private sector finance and enables them to progress along the commercialisation pathway.
- BioStart Fund: Provides access to early stage financing for startup firms.
- Current commercialisation training opportunities will be extended through the
- Mentoring for Growth and Innovation Start-Up Scheme program.
- Queensland Biocapital Fund: Through the QIC to l stage later venture capital financing to ensure the establishment of globally competitive bio-businesses.
- The Government will raise investor readiness by encouraging participation in the Commercialisation Bootcamp and Masterclass Program through the Australian Institute for Commercialisation.
- Smart State Innovation Skills Fund: Providing A$ 12 million to attract and retain leading scientists and build skills in Queensland.

The biotechnology industry in Queensland, therefore, provides a context of strong government support and policy initiatives related to the creation and use of knowledge, with a strong potential role for universities in developing the industry, but also with key governance issues concerning how these processes can be managed and developed for the most effective outcomes, given the different stakeholders involved, both domestically and internationally.

Interviews with key stakeholders, however, also indicated question marks over the (strong) role of government hierarchical-based management in focusing university agendas in particular, in biotechnology and commercialisation. Certainly, universities are seen as having to take more commercial responsibility for managing outcomes.

> ‘The main change has been really almost foisted upon universities by government policy and that is the sense that they have to manage the outcomes of their research, which was never ever something that was really on the agenda in universities. Ten years ago it was that there would be papers published, there would be a contribution to

> the academic arena, but there would not be necessarily be any transfer of that information into commercial value or into industry.' JC

Following this agenda, government funding and start-up programs have reflected in changes of start-up behaviour. Several respondents argued that this may just be an indication of being able to access funds, rather than the policy creating sustainable firms or growth.

> 'For instance, the state government in grants that invest in commercialisation of new technologies have to be granted to a company. So you see universities doing things like forming a small, really, shell company, so they can take an $80,000 ISIS grant or a $100,000 COMET grant because they have to, not because it's necessarily the right vehicle to put that piece of IP in at that point in time.' AMB

Other respondents recognised similar results in start-up behaviour in universities, questioning the "fora" (i.e. starts- ups), as a result being utilised for knowledge dissemination and utilisation :

> 'And part of [the university] their charter was to create X number of spin-outs in a certain amount of time…Whether any of them would be useful or not is another thing and also the state government at that stage had a particular funding scheme that allowed, [name omitted], to set up spin off companies and get funding for them. …They have a certain amount of intellectual property; they're managed by the head of the [name omitted, commercialisation unit] plus a commercial development officer who's working on it part time and it's pretty much a cart without wheels. It just sits there and does nothing.' RIB

The appropriateness of the allocation of funds to public institutions including universities for research and developments versus private institutions and research centres was also questioned by several industry respondents:

> 'You look at the major recipients of funding out of government. Go back and look at the last seven years, since they announced in 1999 that they were going to concentrate on biotech. Have a look at all the funding for life scientists you'll find about 95 percent has gone to universities.' KA

In contrast to the hierarchical governance push on universities and industry from government, commercialisation through spinouts as a way of disseminating knowledge seemed to be more towards a market-based approach than hierarchical. An examination of the commercialisation structures utilised by universities themselves, also highlights a focus on more market-based governance modes, separated from other parts of university management, with continuing conflicts between this and more traditional university approaches.

> 'Commercialisation is not a core business for the University. That's why – I think that's why UQ puts it out into UniQuest, because it's not actually a core business. Whereas their core business is education, teaching.' JC

The inherent challenge for the academic scientist however, is how to manage the additional commercial responsibility produced by these changes:

> 'There's always this tension. When you're outside the system you think "why don't they do this? Surely they want to commercialise what they've done". But when you're in a university you're fighting for grants, you've got PhD students, you've got your teaching work, you've got your research, you've got your administrative duties, and then they want you to commercialise. Yeah, and you've got insecurity of tenure. …' AMB

Role conflicts also occur between the commercialisation agenda and the university bureaucracy and traditional social agendas:

> 'There are additional pressures of managing the conflicting roles within academia. It's actually very difficult to be entrepreneurial in a professional bureaucracy and universities are the classic professional bureaucracy…Essentially universities as professional bureaucracies have really got to – well the mantra is that everybody is equal, okay. But in business, everybody is not equal and that's the dilemma that you have when you're an entrepreneurial scientist in a university.' JC

In terms of geographical clustering as a result of spin-outs, questions were also raised :-

> ‘What is happening is that with the [name omitted] and the [name omitted] and a few other smaller features we are getting clustering but it’s not in the like industry. So you are going to get a few biotechnology firms coming together and we are still getting minor cross fertilisation and some synergy but not to the extent of the actual clustering theory.’ JK

This also highlights the use of universities in knowledge spillover indirectly through the provision of centralised facilities, education and training. This may assist in innovation dissemination in ways other than spinouts, university proximity also being discussed in terms of providing (agglomerational) access to resources.

> ‘You are also finding more satellite-like clusters coming out of universities. I don't think it’s an issue of dependency on the universities. It’s more like a security blanket, of the university is right there, and from the scientists who utilise not only the human capital but also the equipment capital.’ JK

The more-market based current approach to exploitation of university knowledge, in a university model otherwise characterised by more hierarchy-based mechanisms also highlighted the key role of the commercialisation manager, who has to act as a conduit between government and university policy, and the needs of industry and academic scientist. The process of undertaking this role, however suggested much greater use of network-based governance for commercialisation managers, particularly with regard to their relationships with academic scientists.

> ‘Researchers understand that they’ve got to have a conversation with someone that’s knowledgeable before they take that particular publication. [However] clearly you can’t have a commercialisation officer company vetting every publication.’ AMB

The university context also adds another dimension that affects the relationship between the scientist and commercialisation manager, because the commercialisation process is an additional one to that traditionally carried out by academics.

> ‘Remember as business manager, commercialisation manager, you’ve got no power to make people do anything. Particularly in universities. I mean in business you say

> "Okay, if you don't want to do that, you'll have to leave the organisation." In the universities "If you don't want do that, I can't stop you." There's no power within the system.' JC

This highlights the varying motives and outcomes that the commercialisation manager has to manage: the scientist and their motive to publish, the university and their motive to dissuade the scientist to publish if it will reduce the value of the IP and potential returns, and the motives of the commercialisation manager who wants to manage the information to give industry and government a compelling proposition to attract significant funding. Developing a cooperative culture between the business units, universities, and government was therefore recognised as integral to the relationships needed:

> 'So you need people in universities – and there are not many of these people – who can bridge that gap between the science and the science culture and the business and the business culture.' PR

A range of skills are also therefore required for relationship development, maintenance and evaluation between the internal key actors. Specifically, commercialisation managers may be the conduit of information flows between government and policy, the central university research program and academic scientist, and separately, need to manage a plethora of relationships, using and being affected by different governance modes. These include the relationship between the commercialisation unit and scientist, the relationship between the commercialisation unit and the central university research programs.

In terms of the case study firms, these exhibited different outcomes, product definition, age, and thus provide a snapshot of strategic behaviours (entrepreneurial orientation), knowledge asymmetry, and knowledge management.

Table 3 : Case Study Results

Title	Case One (TT)	Case Two(PB)	Case Three (GT)
Type of Firm	Start Up (R & D)	Private	Ceased Operating
Fora for Knowledge	University	Industry	Incubator
Knowledge (IP)	Patents Secured	No Patent until later	8 Patents
Product Definition	Platform is a patented, defined, set of protein complexes	Diagnostic technical platforms includes enzyme-linked immunosorbent assay (ELISA), indirect fluorescent antibody test (IFA) and rapid lateral flow devices	Blood-based monitoring tests for performance animals, initially the performance horse
Stakeholders	Academic Scientist Director Commercialisation Manager	Scientist/CEO, Founding Members, Board of Directors	Academic Scientist, CEO, Board of Directors
University Role	Positive Start Up, Continuing Relationship	Negative Prior Start Up Experience with University	Minor prior commercialisation role at uni , Indirect use of university resources (knowledge) translated to own IP
Government Role (Funding)	Yes	Yes (later)	Yes
Board of Directors	Scientist did not want to be on Board	Scientist is currently on Board	Scientist wanted to be on the Board but did not
Strategic Orientation	Technology Driven: Target: Big Pharmaceutical (further funding)	Customer Driven, Target End customer (Hospitals	Technology/Market Driven. Target: Equine Industry
Knowledge Asymmetry	No	No not for management team, Yes between scientist and board	Yes Various forms
EO: Risk Taking for Scientist	Calculated (Remained in position, though uncertain outcomes, support by stakeholders)	Very High (Customer/market driven) Market Leader	Very High (Scientist left job, International set up)
EO: Proactiveness	Very High (Prioritised)	Very High (Left job, mortgaged house)	High (Opportunities recognised, difficulty with timing and funding)
EO: Innovativeness	Suite of Potential Applications for Platform	Very High (Customer/market driven) Market Leader	Product Definition failure
Knowledge	Yes	High between founding	None (Board and CEO)

Management: Trust		members	
Knowledge Management: Communication	High Weekly, Informal	High, Weekly, Informal at commencement, Reduced as progress (Board vs Management) More Structured as more established	Low ties with Board (proximity?) High level of communication between staff and management
Knowledge Management: Commitment	High	High commitment at commencement	High at commencement Low at cessation
International Linkages	Use of International and bonding networks (informal) in product development, bridging networks in business development	During start up, limited international links as business developed further extensive links including international markets and further links including international partners in continuing product development	International bonding for processes for product development, and sought international markets. Potential to move internationally with pressure from the board increased asymmetric behaviours within the team and created further complications during business development.

In comparing the three cases in terms of the key constructs of knowledge asymmetry, entrepreneurial orientation and knowledge management, the following key differences can be noted. The failed case (3) displayed more knowledge asymmetry, compared with other two. In terms of innovativeness, the failed case exhibits, in particular, a product definition failure, compared with the other cases. In terms of relationships, trust and communication were particularly poor in the failed company compared with the others. Knowledge asymmetric behaviour was exhibited in two cases, both between the scientist and the board of directors with restricted information flow on strategy and science. This lack of communication has further implications for accurate decision making and the 'best way forward' with the potential to make less effective decisions as a team.

All three cases show high levels of entrepreneurial orientation. This is not unusual based on the inherent nature of the biotechnology industry. High levels of proactiveness and risk taking behaviours were seen in cases two and three, with the first case shown moderate risk behaviour. There are interrelationships not only between knowledge management characteristics of trust, communication and commitment but also between elements of communication and commitment and asymmetric behaviours, risk and trust constructs, and knowledge asymmetry and perceived risks. The last case experienced faults in all constructs evaluated, but particularly knowledge asymmetry, and the entrepreneurial orientation and

relationship characteristics. Whilst this does not imply causality for firm failure, it does highlight the complexity of biotechnology firm start-ups as knowledge based entities and the constructs potentially of particular relevance to this.

In terms of the role of cross-locational national and international linkages with a variety of stakeholders, there are particular issues related to attracting and retaining talent in the Australian biotechnology industry highlighted by Stephens et al (2006). Fontes (2006) has also recently highlighted that biotechnology firms may also form collaborator relations with 'distant networks' (Fontes, 2006) to augment their own research and (often-non networked) spillovers from their own localities. This highlights some areas for further debate and research, an issue we now turn to in the conclusions.

Conclusions

This research acts as a starting point, highlighting the need for a more developed understanding of the management and governance processes at work, in this highly important, government policy influenced, industry. The evidence presented here indicates a degree of applicability of the general framework of analysis of knowledge spillovers in knowledge based industries, but also a clear need to develop the framework further, particularly in terms of applying it to wider datasets.

The evidence presented from this initial examination of the Queensland biotechnology industry in Australia clearly highlights a number of different governance modes at work simultaneously, with a strong government hierarchical mode seemingly in place between the main stakeholders of government, industry and universities, an (incomplete) move towards a more market-based regime for universities in dealing with commercialisation, and seemingly more reliance on network-based modes within between the scientists and the commercialisation manager, in dealing with this additional emphasis for universities to commercialise their knowledge.

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